A Study of Roadway Delineation Systems

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The primary objectives of this study are to determine the driver's delineation requirements during various traffic and environmental conditions, establish techniques for determining the effectiveness of delineation treatments, test some of the more promising delineation systems, and develop practical criteria for the selection of delineation treatment systems. This paper describes the techniques utilized in the review of past and current research, the assessment of current practices in the various states and selected foreign countries, and the structuring of information. Particularly relevant findings and conclusions derived from this compilation are enumerated. The definition of driver's delineation requirements through information-decision-action models is described. The IDA analyses are used to transform the driver performance requirements to information requirements; i.e., actions required to effect the desired performance, decisions required to effect the actions, and information required to elicit the desired decisions and actions are identified.

•PRESENT DELINEATION TECHNIQUES include the use of pavement markings, post delineators, raised pavement markers, colored pavements, rumble strips, and curbs. They also include, either intentionally or unintentionally, contrasting shoulders, reflectorized guardrails, rows of luminaires, parallel fence lines, and advertising signs. Only limited information is available concerning the effectiveness of these various devices. Conditions that warrant the installation of the particular type of delineation treatment have not been defined.

Vehicles running off the road constitute a substantial portion of the accidents on the nation's highways. Improved pavement and roadway delineation treatments may aid drivers in controlling their vehicles, thus improving the safety aspects of the highway and easing the driving task, especially during adverse weather conditions and at night. Delineation techniques have also been used to provide guidance and regulatory information for special purposes such as left turns, right turns, speed changes, cross walks, reversible lanes, channelization, no-passing zones, and pavement width transitions. These needs must be recognized in the development of a complete delineation system.

This paper presents a brief summary of the objectives of a research project to study the many facets of roadway delineation, some of the findings from the research review and current practices survey, and a description of the general structure of the project and methodology to be employed.

PROJECT OBJECTIVES AND SCOPE

The specific objectives of the study are as follows:

1. Review past and current research pertaining to roadway delineation.
2. Prepare a summary of the review.
3. Determine the driver's delineation requirements during various conditions such as traffic, weather, highway geometry, and illumination.

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4. Establish rational techniques for determining the effectiveness and the detrimental side effects of delineation treatments. Using the techniques established, evaluate existing and proposed delineation systems.

5. Test the more promising delineation systems by employing, but not necessarily being limited to, one or more of the following: laboratory simulators, off-highway test tracks, and operating highways.

6. Develop practical criteria for the selection of delineation treatments, including factors of cost effectiveness and maintenance.

7. For guidance purposes, evaluate the physical characteristics of colored pavements and compare their performance with that of conventional asphalt and portland cement pavements.

The scope of the study is defined as follows:

1. The maximum benefits of an improved roadway delineation system would probably occur on rural highways, and, therefore, the major project efforts should be directed toward problems associated with rural 2-lane highways.

2. Exit and entrance ramp studies are not considered to be a major part of this research because so many parameters affect the accident rates at these locations that it would be very difficult and costly to determine the effect of delineation.

3. The effectiveness measure should be the system's ability to prevent accidents.

4. Ideally, the cost solution will relate the annual costs of various roadway delineation systems to the predicted accident reductions.

In order to provide a clear and unambiguous interpretation of key concepts, the following operational definitions were formulated and have been adopted as working guidelines for the project.

1. A delineation technique is one of several types of devices or treatments or both, excluding signs not specifically related to a delineation system, that provide guidance, regulatory, or warning information to a driver.

2. A delineation system is a collection of techniques or treatments or both that form an organized pattern or network of information that serves either to distribute or to manipulate vehicular traffic or to do both over a specified section of roadway for a specific purpose. For example, a delineation system might consist of an early cue sign, a color-coded deceleration lane marker, edge striping, gore signs, color-coded reflective delineators for ramp and main stream, and quite possibly colored pavement (collection of techniques and treatments). The sequencing and placement of these components (an organized pattern or network) would indicate to drivers in the vicinity of interchanges (a specified section of roadway) how and where the exiting drivers should effect their exit maneuver (specific purpose) in order to avoid disruptions in the main stream flow (distribution and manipulation of vehicular traffic).

RESEARCH APPROACH

Literature Review

Lists of articles and reports pertinent to this project were obtained from the Highway Research Board, the National Highway Safety Bureau, and references in the literature located from these lists.

A literature review card was prepared for each article found. Included on each of these cards was a preliminary abstract of the article and comments concerning its relevance to the project. Copies of relevant articles were obtained and a final detailed abstract prepared.

An indexing scheme was developed early in the program to facilitate information retrieval. The major classification structure consisted of the various situations for which delineation is required versus the delineation treatments used. Additional categories were added as necessary to clarify the nature of the information included in the specific report.

A matrix of the classifications was constructed on which the identifying article numbers were entered in the cells. This master index sheet provided a visual indication

TREATMENT / SITUATION	A. GENERAL	B. COLOR PAVEMENTS	C. PAVEMENT MARKING	D. RAISED DELINEATORS	E. POST DELINEATORS	F. SIGNS	G. CURBS	H. RUMBLE STRIPS	I. INDIRECT METHODS	J. SYSTEMS	a. HUMAN FACTORS	b. TRAFFIC CHARACTER	c. COSTS	d. ACCIDENTS	e. MATERIALS	f. MAINTENANCE	g. ENVIRONMENT EFFECTS	h. COLOR CODING	i. CURRENT USAGE	j. THEORY & EXPER.	k. NEW IDEAS & MAT'L	l. METHODOLOGY
1. GENERAL	10	16	42	15	8		3	3	5	2	10	7	10	16	16	7	8	6	5	4	9	11
2. TANGENTS		1	17	8	4		2		2		5	7	4	8	4	2	6	1			5	5
3. CURVES (HORIZ)	1		11	4	4		2		1		6	7	2	7	1	1	5	1	1		2	6
4. CURVES (VERT)			5		1						1	1	1		1	1	1	1	1		1	1
5. WIDTH TRANS			3								1	1						1	1			1
6. TURNS		7	6	1		1	1	2	2		1	6		8	2	1	1	5	1	1		1
7. EXIT RAMP		3	11	1	6				1	6	4	7	2	1	3	1	3	6	1	1	2	4
8. ENTRANCE RAMP		2	7		4				1	4	4	3			1		3	4	1	1	1	2
9. CROSS WALKS		1	6									1	3	1	4	2					1	
10. R.R. APPROACHES			1									1										
11. OBSTRUCTIONS		3	2						2			1		2	1		1	2	1			
12. PULL-OFFS																						
13. PASSING LANES			4	1							2	2	1	2	1	1	2		1			1
14. CROSSING & WEAVING			1									1										
15. MERGING & DIVERGING			2		1	1						1	1	1	1	1				1		
16. REVERSIBLE LANES	1		1	1		1									1	1						
17. CLIMBING LANES		1	1												1				1			
a. HUMAN FACTORS	3	2	10	6	2	1	1	1		4												
b. TRAFFIC CHARACTER	1	2	19	2	5			1	1	4												
c. COSTS	1	4	20	7	3		2			1												
d. ACCIDENTS	6	2	12	4	3			1	5	1												
e. MATERIALS	3	16	26	15	2	1	3	4	1	1												
f. MAINTENANCE		1	12	8	2																	
g. ENVIRONMENT	2	4	7	9	2		1															
h. COLOR CODING		12	7	1	4	1				6												
i. CURRENT USAGE			5	3	1																	
j. THEORY & EXPER			4	2	1			2		1												
k. NEW IDEAS & MAT'LS		1	9	9			2															
l. METHODOLOGY	4	2	14	1	5					4												

Figure 1. Classification structure and number of articles recorded on master index sheet.

of the amount of literature available regarding any specific treatment combination. Figure 1 shows the categories and the number of articles entered in each of the cells of the master index sheet.

Review of Current Delineation Practices

It was originally proposed that information on current delineation practices would be requested from all highway departments by a form letter. However, because of the difficulty in designing a simple questionnaire that would cover the necessary topics thoroughly, the anticipated low response rate, and the consequent questionable accuracy, visits were made to a sample of state highway departments to conduct interviews and view actual delineation practices in those states. The visits made it possible to collect much more detailed information regarding current delineation practices and problems then would have been possible through the use of a questionnaire; to explain the program to various highway traffic engineers and obtain their reactions and comments; and to determine the type content and organization of reports and manuals highway engineers would like to see as an end product of this project.

Prior to the final planning for these visits, a letter was sent to each of the 50 state highway departments requesting the following items: manuals, policy statements, and warrants that explained current roadway delineation practices; research reports, project progress reports, and other available literature related to roadway delineation; and any other comments pertinent to the study. Thirty-five states and the District of Columbia answered this letter.

Based on the replies from the letters and a desire for geographical distribution, visits were made to 11 state highway departments. In general, these visits included a description of project goals and research approaches by project personnel, an interview based on a prepared interview form modified to reflect any prior reports or information acquired concerning the specific state to be visited, informal discussions with personnel in the highway department, and on-the-road inspections of delineation practices. Visits were made to Arizona, California, Colorado, Florida, Michigan, Montana, New Hampshire, North Carolina, Ohio, Pennsylvania, and Texas.

In addition, letters were sent to 21 countries and the Economic Commission for Asia and the Far East (ECAFE) requesting copies of any published material on delineation practices, statements regarding particularly effective treatments and especially difficult problems, and information on any experiments under way. Manuals from 7 countries and a code on pavement markings in the ECAFE region were received.

Driver Delineation Requirements

The approach adopted in determining the driver's delineation requirements consisted of an analytical review of the literature, data from the current practices survey, and field observations. This approach was twofold in that one aim was to define the purpose of current delineation systems, and another was to establish for all situations, regardless of delineation treatment, what the driver's information requirements are. Each delineation situation was reviewed and specific performance or task requirements identified. An information-decision-action (IDA) analysis was used to transform the performance requirements to information requirements; i.e., actions required to effect the desired performance, decisions required to effect the actions, and information required to elict the desired decisions and actions were identified.

The application of the IDA technique to a large number of situations revealed that the majority of these situations, initially assumed to be different, were highly similar in terms of IDA elements. Thus, redundancies and ambiguities in the situation classification process were avoided by determining which situations required unique IDA models. This resulted in the identification of a number of classical or typical situations that collectively exhaust the normal range of maneuvers required of the drivers over the usual geometric conditions encountered today.

The situation selection effort was, in effect, an iterative review process designed to avoid undue model development because the literature was severely lacking in the quantitative data needed to either support or generate or both the qualitative aspects of the IDA sequences. Each iteration was based on the successive adoption of guidelines designed to reduce the total number of situations modeled and at the same time to exhaust the unique classical situations such that no critical driver requirements would be missed.

Thus, the classical situations were selected such that the integral maneuvers could be combined to produce any situational complex not specifically modeled. (The weaving area, for example, is a straightforward combination of the merge and diverge situations.)

In all, 4 iterations were required to select and develop the final situation models. Guidelines employed in each of the 3 review and selection cycles and those that deal with model development are as follows:

Iteration 1

1. Catalog all guidance, control, and warning situations.
2. Distinguish the geometry and the maneuver.
3. Define an exhaustive set of geometry-maneuver combinations.
4. Eliminate all highly similar situations but one.

Iteration 2

5. Review remaining situation list of common elements.
6. Assess demand on driver in terms of stimulus and response loading.
7. Sort maneuvers on basis of nature of observable control elements—continuous and discontinuous.
8. Classify discontinuous elements as turn maneuvers or acceleration-deceleration.
9. Classify continuous elements as adjustments in lateral position or adjustments in longitudinal position such as spacings.
10. Identify decision and action requirements.
11. Tabulate driver's alternative action choices (simple or multiple).
12. Determine whether actions are discretionary or dictated.

Iteration 3

13. Review classification structure in iteration 2 for commonalities in geometry-maneuvers.
14. Select situations to typify each geometry-maneuver class—the classical situations.
15. Classify original situations according to "best-fit" class.

Iteration 4

16. Review, delete, add to, and modify the classical situations until model situations are developed that contain measureable action elements.
17. Identify critical interactions among the action elements.
18. Eliminate unneccessary decision alternatives to simplify the modeling.
19. Generate assumptions for subject vehicle trajectory or ideal path.
20. Generate assumptions for detailing geometry, maintaining a balance between generality and specificity.
21. Gather quantitative and qualitative supportive data to apply to the assumptions in 19 and 20.
22. Select evaluative measures.
23. Construct requirements flow chart and situational diagrams.

The results of these efforts have been presented in an interim report.

COMMENTS OF STATE HIGHWAY DEPARTMENT PERSONNEL

During the interviews with the personnel of the various state highway departments, an attempt was made to determine their feelings as to how this research project could best serve their needs. The answers were quite varied and, of course, were spontaneous and represented only the personal views of the person or persons being interviewed. The principal needs expressed in the comments are as follows:

1. A compilation of the physical properties, wear characteristics, and costs for the various materials available on the market.
2. Instead of product information, a report summarizing the current delineation practices of the various states for given situations.
3. Selection of the one delineation treatment that would have the most universal application and uniformity in application, installation, and maintenance.
4. Instead of compilations of product information and summaries of current practices, solutions to specific problems; e.g., where should edge lines be placed on wide pavements, which is the proper spacing and pattern for raised pavement markers, and are edge lines superior to contrasting shoulders?
5. A comparative evaluation of raised pavement markers and post delineators on urban expressways.
6. Effectiveness of colored pavements as delineation treatments and data on their wear and skid characteristics.
7. New delineation techniques and concepts.
8. Cost-effectiveness because fundings for delineation are not adequate to permit extensive utilization of most treatments other than painted lines.

In general, the various states have not devoted any special or particular attention to overall delineation practices; the Delineation Task Force in California is an exception. This is not to imply that they do not feel delineation to be important, but to indicate that they generally handle it as a part of their overall operations and usually give it somewhat less attention than they give to signing.

PRELIMINARY FINDINGS

The efforts directed toward the preparation of a summary of roadway delineation systems and the determination of driver delineation requirements are of such a nature that no experimental findings have been obtained. However, some of the conceptual findings and statements presented in the interim report are summarized in the following paragraphs.

1. No universally accepted technique has been developed to evaluate the effectiveness of the various possible treatment systems in meeting delineation needs. Even where rankings of treatment systems can be established, no means is available to determine cost-effectiveness relationships.
2. Driver-information needs can be portrayed effectively through the development of situation-oriented models. These models will be useful in the structuring of future research efforts (project and nonproject) and in the development of meaningful recommendations for delineation treatment systems.
3. The majority of states use edge linings on rural 2-lane roads; most have warrants excluding edge lining on pavements under 22 ft in width. Effects of edge lining on accidents is still somewhat questionable, though no adverse experiences are reported. Lateral placement and speeds are frequently affected, but potential accident reductions as a function of these parameters have not been established.
4. Today's longitudinal line patterns are primary continuations of historical patterns. Various states attempt to simulate these same patterns when installing raised pavement markers. Little research on optimum patterns has been reported.
5. Basic philosophical differences exist as to the proper placement of edge lines on wide 2-lane highways (40-ft crown widths). Some claim they should be placed at the 12- or 13-ft point; others say near the edge of the pavement. Texas is experimenting with a painted, traversable median on these wide roads (Fig. 2).
6. The quality of driver performance will be reduced if too much information is given too fast, if actions must be accomplished in very rapid succession, or if the information provided leaves the driver in doubt regarding precisely what action he should

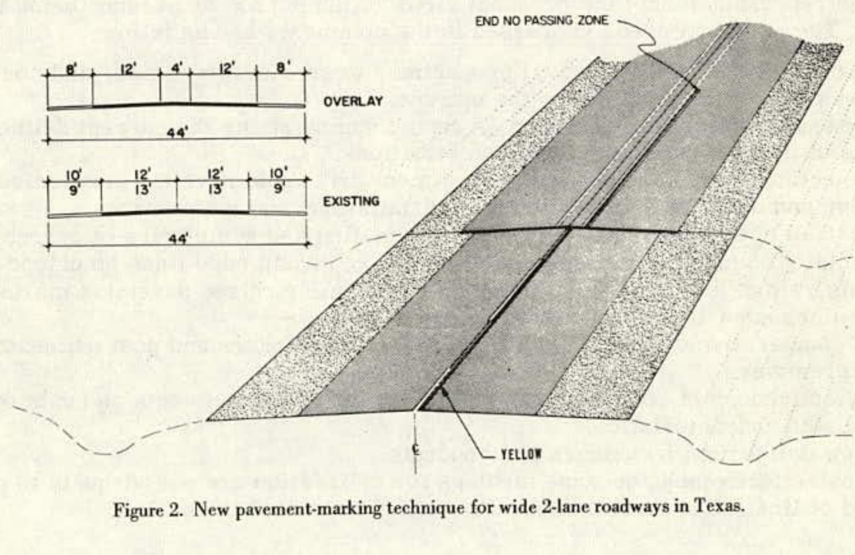

Figure 2. New pavement-marking technique for wide 2-lane roadways in Texas.

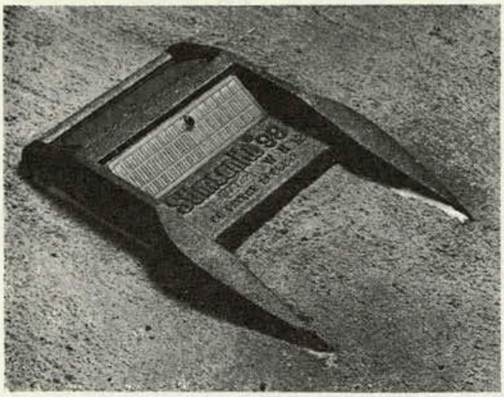

Figure 3. Stimsonite 99 "snowplowable" marker.

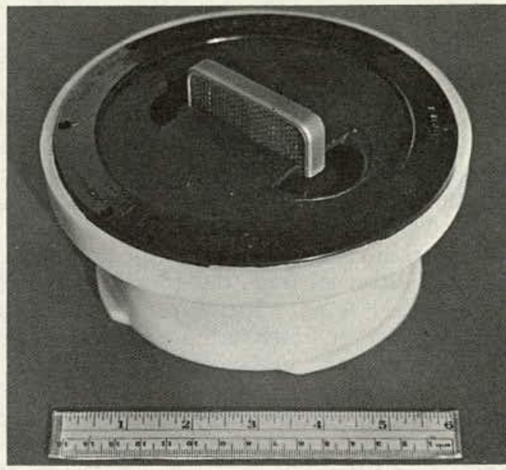

Figure 4. Traffic standard Kone-Lite "snowplowable" marker.

take. Applications of delineation treatments must be designed to lessen the effects of these conditions by providing advance information or by deliberate and careful use of redundancy or both.

7. The detecting power of the eye (sensitivity) is generally both more important and more easily capitalized on in the driving situation than the resolving power (acuity).

8. Standard paint, with or without reflectorizing beads, is the most commonly used pavement-marking material for rural highways. Thermoplastics are gaining acceptance in urban areas where there are high volumes and special situations. The relative cost of thermoplastic striping (approximately 15 times that of paint striping) has discouraged its use on rural highways.

9. Although a wide variety of raised pavement markers are being used, no single marker has been developed that is suitable for both day and nighttime. At least 2 firms are developing raised pavement markers claimed to be suitable for areas requiring snow removal, but adequate field evaluation is not available to date (Figs. 3 and 4).

10. The widespread use of colored pavement has been impeded by the lack of agreement on color usage, ineffectiveness of colors at night and their tendency to fade with time, expensive materials, and no adequate demonstration of the effectiveness of colored pavement as a delineation treatment.

Figure 5. Pavement markings for ramps in Japan.

11. Interviews with visitors to and from European countries and findings of the limited literature survey conducted suggest that delineation receives relatively more attention in those countries.

12. Several countries, including England and Germany, use white only for pavement markings. Most other countries use a 2-color system, usually white and yellow.

13. Markings between through-lanes and speed-change lanes are generally more pronounced than in this country. Several countries use wide dashed lines and carry them throughout the length of acceleration and deceleration ramps (Fig. 5).

14. Thermoplastic lines are used much more extensively in Europe. The initial cost, as compared to painted lines, is approximately 3 to 1 in England, which is considerably different from the 15 to 1 ratio in this country.

15. There is very little in the existing methodology of benefit-cost analysis that can be applied directly to the evaluation of benefits of improvements in highway delineation systems.

16. It is unreasonable to insist that every benefit pertinent to the benefit-cost analysis be quantified. This insistence will lead either to the exclusion from consideration of all benefits except those that are capable of quantification or to the use of a meaningless quantification of nonquantitative benefits or costs, e.g., the use of arbitrary numbers to represent pain and fear in accident cost studies.

ACKNOWLEDGMENTS

This research project was awarded by the Highway Research Board through the National Cooperative Highway Research Program to the Pennsylvania State University on October 1, 1968. Subcontracts were subsequently let to the Institute for Research and to Wayne State University. The primary efforts of the Institute for Research are toward the human aspects of the study and are directed by Edmond L. Seguin. Wayne State University's efforts are in providing assistance in the studies of colored pavements and accident records analysis and are under the direction of William C. Taylor. An interim report has been prepared that presents the results of research efforts relating to objectives 1, 2, and 3, listed earlier in this paper.